* polarization (Direction of an Electric Field)

Types of polarization

① linear polarization

Direction of the electric field doesn't change while the wave propagates

$$E = E_{01} \cos(wt - \beta z)\, \hat{a}_x + E_{02} \cos(wt - \beta z)\, \hat{a}_y$$

and E is constant

$$\theta = \tan^{-1} \frac{E_{02}}{E_{01}}$$

Types of Linear ~~polarizatio~~

① vertical polarization → Electric field is vertical

② Horizontal polarization → " " " Horizontal

③ linear polarization → " " " Linear

2. Circular Polarization

$$\bar{E} = E_{01} \cos(\omega t - \beta z)\, \hat{a}_x + E_{02} \cos(\omega t - \beta z + \phi_0)\, \hat{a}_y$$

$$\phi_0 = \pm 90^\circ \quad (\text{clock wise ; anti clock wise})$$

$$E_{01} = E_{02} = E_0 \quad (\text{always})$$

and so ;

$$|E|^2 = E_0^2 \left[\cos^2(\omega t - \beta z) + \underbrace{\cos^2(\omega t - \beta z + 90^\circ)}_{\sin^2(\omega t - \beta z)} \right]$$

$$\therefore |E_0|^2 = E_0^2 \underbrace{\left(\cos^2(\omega t - \beta z) + \sin^2(\omega t - \beta z) \right)}_{=1}$$

$$= E_0^2$$

Eqn for circle

$$x^2 + y^2 = |E_0|^2$$

Scanned by CamScanner

(3) Elliptical polarization

$$E_{o1} \neq E_{o2}$$

$$|E_o|^2 = x^2 + y^2 = E_{o1}^2 \cos^2(\Omega) + E_{o2}^2 \sin^2(\Omega)$$

$$\therefore x = E_{o1} \cos(\Omega)$$

$$\therefore y = \pm E_{o2} \sin(\Omega)$$

Ellipce eqn

$$\therefore \left(\frac{x}{E_{o1}}\right)^2 + \left(\frac{y}{E_{o2}}\right)^2 = \sin^2(\Omega) + \cos^2(\Omega)$$

$$\therefore \left(\frac{x}{E_{o1}}\right)^2 + \left(\frac{y}{E_{o2}}\right)^2 = 1$$

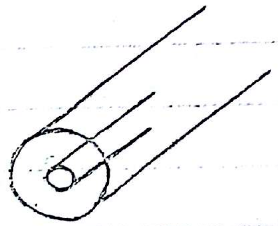
Transmision Lines

→ Air → (unguided Wave)
wave propagate in unbounded medium
and used in radio, TV and broadcasting

→ Tx lines → Guided ; Direct

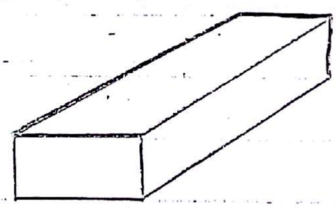
III Types of transmision lines

① Co-axial line

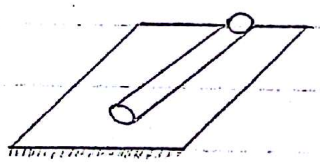


② two-wire line

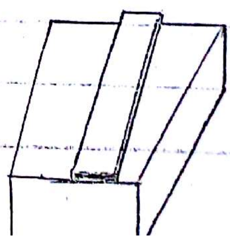
③ ~~planar line~~



④ wire above conducting



⑤ microstrip Line



[2] Transmission line parameters

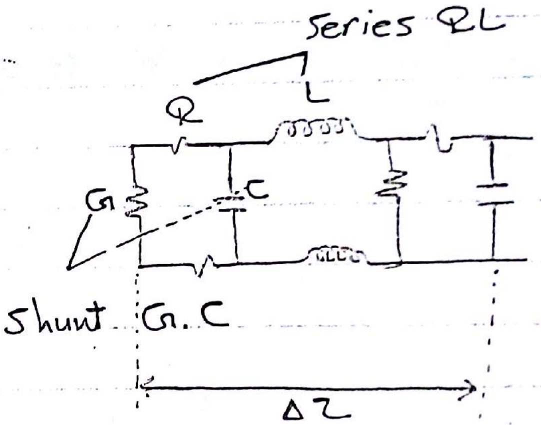
R → resistance per unit length for Conductor.

L → Inductance per unit length " ".

G → Conductance per unit length due to dielectric.

C → Capacitence per unit length for ".

- Assuming two conductor T.L of length (ΔZ)



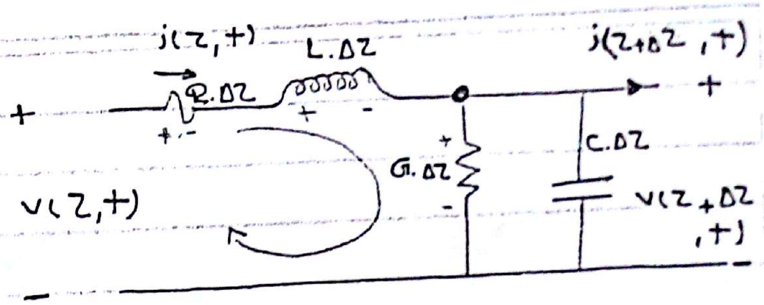
$$R_{tot} = R \cdot \Delta Z$$

$$L_{tot} = L \cdot \Delta Z$$

$$G_{tot} = G \cdot \Delta Z$$

$$C_{tot} = C \cdot \Delta Z$$

Derive an expression for the wave equation of a T.L



① Applying K.V.L

$$v(z,t) = i(z,t) \cdot R.\Delta z + L.\Delta z \frac{d(i(z,t))}{dt} + v(z+\Delta z,t)$$

$$v(z,t) - v(z+\Delta z,t) = i(z,t) \cdot R\Delta z + L\Delta z \frac{di(z,t)}{dt}$$

$$\frac{v(z,t) - v(z+\Delta z,t)}{\Delta z} = i(z,t) \cdot R + L \frac{d\, i(z,t)}{dt}$$

by taking $\lim_{\Delta z \to 0}$ for two sides

$$-\frac{\partial v(z,t)}{\partial z} = i(z,t) \cdot R + L \frac{di(z,t)}{dt} \longrightarrow ①$$

② Applying K.C.L at node (•)

$$i(z,t) = v(z+\Delta z,t) \cdot G\Delta z + C\Delta z \cdot \frac{\partial v(z+\Delta z,t)}{\partial t} + i(z+\Delta z,t)$$

$$\frac{i(z,t) - i(z+\Delta z,t)}{\Delta z} = v(z+\Delta z,t) \cdot G + C \frac{d\, v(z+\Delta z,t)}{dt}$$

$$-\frac{\partial i(z,t)}{\partial z} = v(z,t) \cdot G + C \frac{d\, v(z,t)}{dt} \rightarrow ②$$

- The Frequency domain representation of T.L

$$-\frac{d\,V(z)}{d(z)}\, e^{j\omega t} = R\, I(z) \cdot e^{j\omega t} + j\omega L\, I(z) \cdot e^{j\omega t}$$

$$-\frac{d\,V(z)}{dz} = (R + j\omega L)\, I(z) \rightarrow ③$$

$$-\frac{d\,I(z)}{dz} = (G + j\omega C)\, V(z) \rightarrow ④$$

From ③ & ④

$$-\frac{d^2 I(z)}{dz^2} = (G + j\omega C) \cdot \frac{d\,V(z)}{dz}$$

$$\frac{d^2 I(z)}{dz^2} = (G + j\omega C) * -(R + j\omega L)\, I(z)$$

$$\frac{d^2 I(z)}{dz^2} = \underbrace{(G + j\omega C)\,(R + j\omega L)}_{\gamma^2}\, I(z)$$

$$\therefore I(z) = I^{+} e^{-\gamma z} + I^{-} e^{\gamma z}$$

$$V(z) = V^{+} e^{-\gamma z} + V^{-} e^{\gamma z}$$

* $\gamma^2 = (R + jwL)\ (G + jwC)$

$= RG - w^2 LC + jw(LG + RC)$

* $\gamma = \sqrt{\underbrace{(R + jwL)}_{Z}\ \underbrace{(G + jwC)}_{Y}}$

$= \sqrt{Z\,Y}$

Secondary Parameters

[1] T.L Charactristic impedance "Z_o"

$V(z) = V_o^+ e^{-\gamma z} + V_o^- e^{\gamma z}$

$I(z) = I_o^+ e^{-\gamma z} + I_o^- e^{\gamma z}$

$\therefore Z_o = \frac{V_o^+}{I_o^+}$ or $Z_o = \frac{V_o^-}{I_o^-}$

$$\therefore \quad \frac{dV(z)}{dz} = -(R + j\omega L)\, I(z)$$

$$\therefore \quad I(z) = \left(\frac{-1}{R + j\omega L}\right) \frac{dV(z)}{dz}$$

$$= \left(\frac{-1}{R + j\omega L}\right) \frac{d}{dz}\left(V_0^+ e^{-\gamma z} + V_0^- e^{\gamma z}\right)$$

$$= \left(\frac{-1}{R + j\omega L}\right) \left(-\gamma V_0^+ e^{-\gamma z} + \gamma V_0^- e^{\gamma z}\right)$$

$$\therefore \quad I_0^+ e^{-\gamma z} + I_0^- e^{\gamma z} = \frac{\gamma}{R + j\omega L} V_0^+ e^{-\gamma z} + \frac{-\gamma}{R + j\omega L} V_0^- e^{\gamma z}$$

$$\therefore \quad \cancel{I_0^+ = \frac{\gamma}{R + j\omega L} V_0^+}$$

$$\frac{V_0^+}{I_0^+} = \frac{R + j\omega L}{\sqrt{(R + j\omega L)(G + j\omega C)}}$$

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

Assuming that (lossless T.L)

$$\alpha = \text{zero} \qquad R = 0 \qquad G = 0$$

$$\gamma = j\beta$$

$$\therefore \gamma = \sqrt{(\cancel{R} + jwL)(\cancel{G} + jwC)}$$

$$= \sqrt{jwL \cdot jwC}$$

$$= jw\sqrt{LC}$$

$$\therefore \beta = w\sqrt{LC}$$

$$\therefore \lambda = \frac{2\pi}{\beta} = \frac{2\pi}{\frac{2\pi f}{}\sqrt{LC}} = \frac{1}{f\sqrt{LC}}$$

$$\therefore u = \frac{w}{\beta} = \frac{1}{\sqrt{LC}}$$

$$Z_o = \sqrt{\frac{\cancel{R} + jwL}{\cancel{G} + jwC}}$$

$$= \sqrt{\frac{L}{C}}$$

* Assuming Distortionless line

① $\alpha \rightarrow$ independant on frequency

② $\beta \Rightarrow$ linearly dependant on frequency

③ $\frac{R}{L} = \frac{G}{C}$

$RC = LG$

* $\gamma = \sqrt{(R + jwL)(G + jwC)}$

$= \sqrt{R(1 + jw\frac{L}{R}) \cdot G(1 + jw\frac{C}{G})}$

$= \sqrt{RG}\,(1 + jw\frac{C}{G})^{2/2}$

$= \sqrt{RG}\,(1 + \frac{jwC}{G})$

$= \sqrt{RG} + j\frac{wC}{G}\sqrt{RG}$

$= \sqrt{RG} + j\,w\sqrt{LC}$

$\alpha = \sqrt{RG}$ $\quad\quad \beta = w\sqrt{LC}$

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$= \sqrt{\frac{R\left(\cancel{1 + j\omega \frac{L}{R}}\right)}{G\left(\cancel{1 + j\omega \frac{C}{G}}\right)}} = \sqrt{\frac{R}{G}} = \sqrt{\frac{L}{C}}$$

$$\frac{C}{G} = \frac{L}{R}$$

Example

An Air line has characteristic of $70\,\Omega$ and phase Constant of 3 rad/m at 100 MHZ.

Calculate the inductance /m and the capacitance /m

— Solution —

Air $\Rightarrow$ lossless line

$\therefore \alpha = 0 \quad ; \quad R = G = 0$

① $Z_o = 70\,\Omega$ $\qquad \therefore 70 = \sqrt{\frac{L}{C}} \rightarrow$ ①

② $\beta = 3$ $\qquad \therefore 3 = (100 * 10^6) * 2\pi * \sqrt{LC} \rightarrow$ ②

from ① substitute ②

$L = 334.2$ nH /m

$C = 68.2$ PF /m